ENGINEERING CASE LIBRARY

ECL 9

URBAN TRANSIT (A)

Urban Transportation and the San Francisco Peninsula

Those who have driven the streets and freeways of the San Francisco Peninsula at rush hour are well acquainted with traffic congestion, the main problem of urban transportation today. A number of modes of urban transportation are available, but the private auto is the most used, and its use is expected to increase. Several alternative schemes for urban transportation have been suggested, but so far no radically new schemes have been adopted by any cities Forecasters generally agree that the problems can be expected to get worse.

The Present Situation

Automobile usage on the San Francisco Peninsula is high. San Francisco reportedly has the highest number of autos per capita of any major city in the United States. In Palo Alto, where the human population grew 120% between 1950 and 1964 (22,500 to 56,000) the auto registrations grew 300%[1] Farther down the Peninsula in Santa Clara County, streets cover approximately 25% of the developed area, compared to 1.6% for rails and 0.8% for airport lands. One report on Santa Clara County stated:

> There is only a slight correlation between residence of employee and place of employment. Traffic flow studies reveal a cross vehicular pattern throughout the north county.
>
> ....
>
> Owing to the type of goods produced and other factors, trucking is and should remain the largest media for transporting in the county.[2]

Two familiar discomforts of heavy traffic are inconvenience and high accident rate. Another is smog. The Los Angeles Air Pollution Control District has estimated that 80% of that city's smog is caused by automobile exhaust. As the auto population has grown, smog has also become a problem for the San Francisco Peninsula. Tha California Board of Health

1. Source: Palo Alto Chamber of Commerce.
2. "An Industrial Analysis of North Santa Clara County", Paul F. Griffith and Ronald L. Chatham, Stanford, 1958

 Prepared in the Design Division, Department of Mechanical Engineering, Stanford University by John M. Leslie and Karl H. Vesper as a basis for engineering class projects.

says air should contain no more than 0.15 parts of oxidents per million parts of air. Between 1954 and 1960 the number of days in which this limit was exceeded for the Santa Clara Valley rose from 6 to 49 per year.[1] It is hoped that the smog control devices soon to be required on all autos in California will help alleviate this problem. Auto manufacturers and others are also exploring possibilities for electrically powered cars.

Other means of transport are available on the Peninsula, but as in most other large metropolitan areas of the U. S., they have not flourished. Commuter trains carry 12,000 people per day between the Peninsula and San Francisco, but are not operating near capacity. Some local trains have been discontinued as recently as the past few weeks due to insufficient usage. Bus service has also become less abundant as the demand has declined, the lowered availability thereby leading to still lowered demand. In Palo Alto approximately 40% of the operating costs of local buses must be paid out of taxes because fares are insufficient.

The pattern has been similar to that of other cities such as Los Angeles, New York, and St. Louis where private bus companies became so unprofitable due to lack of demand that municipal governments had to take over for service to continue. A similar transfer of ownership is now under way in San Diego. In Chicago, the rapid transit service, which has capacity to carry 33,000 people per hour past a point on each track, is only carrying 1/3 of its capacity. The total number of trips on public carriers made by Americans dropped for 24 billion in 1946 to 11 billion in 1960[2] although the population was growing.

Use of automobiles for transit, however, has been growing continually, faster than the human population. Between 1946 and 1960 the number of trips made by auto in America rose from 25 billion to 50 billion. In San Francisco, where the human population has stayed about level, the number of auto trips per average weekday grew from 915,000 in 1947 to 1,212,000 in 1958 and has been estimated to reach 1,800,000 by 1975. Most of these trips were probably made during the rush hours. The graph in Exhibit 1 shows traffic as a function of time of day for Chicago, as an example. Chicago has predicted that travel by autos will have doubled between 1956 and 1980, while travel by public carriers there will increase little if any. There are now about 60 million autos in the US accruing an average of 10,000 miles per year. In contrast, there are about 50,000 buses, 3,000 being built per year.

Surveys indicate that the traveler's main concern is time door-to-door. Secondary are comfort and cost. Autos have gained advantage in speed as freeways have been built and limits have been raised. On highways, the average speed of autos increased from 48 miles per hour, in

1. <u>Oxident Concentrations in the San Francisco Bay Area Network: 1954-1960</u>, Bay Area Air Pollution Control District.
2. American Transit Association.

1942 to 54 in 1961.[1] Buses average 13 miles per hour, about half the average for autos in town. In addition, autos usually offer the advantage of greater flexibility and privacy, although they are not more economical. Operating costs average $.04 per mile (autos carry an average of 1.6 passengers each) for autos versus $.07 per mile for a 50 seat bus and $.65 for an 80 seat rail car.

From a public point of view, however, automobiles can be even more expensive. The various governments spend about $10.7 billion per year on roads, while taking in only $10 billion in gas taxes, tolls and fees on automobiles. Space is another expense, the average auto requiring about 9 times as much as a passenger in a public conveyance. The paved area for autos, including parking lots, in downtown Los Angeles now covers 50% of the total area. A lane of freeway costs less than one of rail, about $1.2 million per mile versus $3 million, but the maximum traffic rate per lane is around 1,500 autos at present, whereas a rail can carry 30,000 seats per hour past a point.

Alternatives Suggested

Solutions to the transportation problem which have been suggested range from slight modifications of present systems to introduction of radically new systems. Thus far, no radical changes have been made or definitely planned on any major scale. Among the suggestions have been the following:

1. Increase of capacity with present systems, particularly by adding more highways and rail complexes. Some experiments are being conducted with monorails, although monorails would not operate much differently from the passenger's point of view than normal rail systems. The investment required for rail systems is generally considered too great for cities of less than 1 million people.

2. Change of people's travelling patterns. Subsidies might be increased for mass transit systems such as subways and buses, and tolls might be imposed on automobile usage to discourage it.

3. Bus Expressways. Special roadway lanes could be built for buses to permit higher speeds. Each bus would circulate through a community to pick up passengers, then enter the special expressway for rapid passage to more distant points.

1. Highway Statistics, Bureau of Public Roads, 1961.

4. Taxi-Buses.. The traveler would phone when he wanted to go somewhere. A central dispatching office would tell him when a bus would be in his neighborhood to pick him up at his door. The bus would be scheduled on an optimum basis to deliver each of several passengers to his destination as directly as possible. Special small buses designed for the purpose would be used.

5. Conveyer-cars. A supply of small cars would be waiting at the station. The traveler would get into one and immediately the car would enter the track toward the station he selected. The system would be automatically controlled.

6. Highway control of autos. The driver would leave home in his car and drive to the automatic highway. Upon entering the highway, he would relinquish control to an automatic system connected to the highway. This system would guide his car, steering and maintaining proper spacing relative to other cars. Near his destination he would leave the highway and drive the remaining way on conventional streets.

7. Rental cars for traveling to and from rail and bus terminals.

8. Moving sidewalks - Conveyer belts and escalators could move people in downtown areas at speeds from 1 to 3 miles per hour. People could step on and off wherever they wished.

9. Accelerated access. People would move to rapid continuously moving trains or conveyer belts via acceleration platforms or special cars to match relative speeds. At destinations, the reverse procedure would allow exit.

10. Waterborne vehicles. For cities near bodies of water, like the San Francisco Bay, ground effect machines capable of running over land or water might be used. Low economy and difficulty of starting, stopping and turning are the main obstacles at present.

11. Land-air vehicles. Some combination of automobile and aircraft, capable of taking off and landing on highways or on special strips alongside highways, might be devised to add another dimension of freedom and hence more space for traffic movement. Helicopters are already used in some cities, but they all presently operate at a substantial loss and they require special landing space.

Present Plans for the Future

Many highway building projects have been definitely scheduled for the next few years. The $41 billion, 41,000 mile Federal Interstate Highway building program is to run until 1972.[1] It has been estimated that US cities over 1 million in population will spend about $40 billion in the next 20 years on construction of new metropolitan transportation systems, 75% going to freeways. On the San Francisco Peninsula construction of several highways is now under way and more are planned. The Federal government, however, is also extending funds to local communities to explore alternative transportation systems. The Greater Association of Bay Area Governments (ABAG), representing 9 counties of the greater San Francisco area, has applied for funds to make a study of alternatives.

For San Francisco and East Bay cities, a rail system, called Bay Area Rapid Transit (BART) is now being constructed. Studies for this system, which is to cost 1.1 billion dollars and should be operational in 1968, have been underway since 1953. A list of design objectives taken from a BART brochure appears as Exhibit 2. The system is to have a capacity comparable to other rail systems. Innovations claimed for the BART system are: (1) greater automation in scheduling, dispatching and operating, (2) use of AC instead of DC power, (3) more stable lightweight cars, (4) quieter operation, and (5) air conditioning. The system is not expected to be highly profitable, but is expected to break even on costs not including amortization of the initial investment. Initially, the system will be confined to the East Bay and San Francisco, but some have proposed that it be extended further down the Peninsula. A map of the BART system appears as Exhibit 3.

No decision has been made by Peninsula communities to support further extension of BART. A main objection is that it will likely require substantial increases in taxes to cover investment and operating costs. Another is that the congestion of traffic around the towns and to and from the stations of BART will not be alleviated.

City planners of the Peninsula agree that some action will clearly have to be taken to provide transportation for a rapidly growing population. The Peninsula now has a population of 1.3 million. By 1980 it is expected to have passed 2 million, and by 2000 to have reached 3 million. By 1980 the California State Division of Highways estimates there will be one vehicle for every 1.85 persons.[1] Some planners hope the number of autos will not rise that high. One community plan calls for

1. The California Freeway System, Sacramento, September, 1958.

"an air transport system serving local as well as inter-regional traffic." The particular means of air transport are not described.

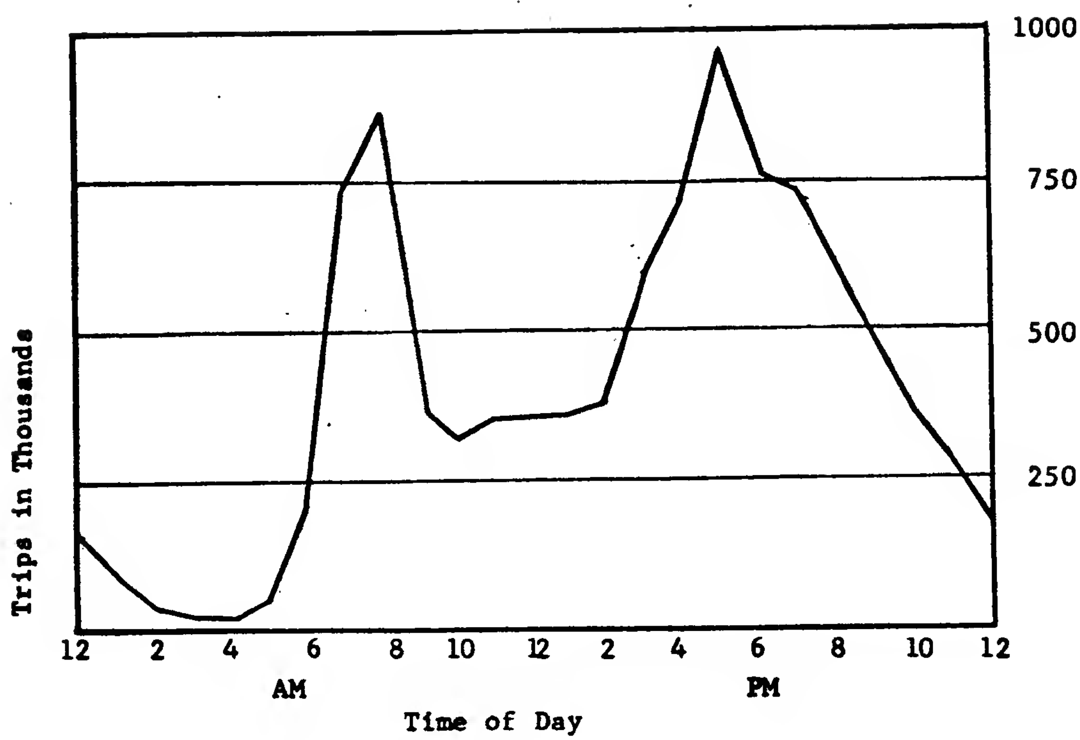
The plan for one Peninsula county, Santa Clara County, calls for another approach: "Rather than aiming at maximum mobility, transportation planning might be aimed at greater convenience through a more desirable urban land development pattern. Possible solutions include: (1) providing places of residence closer to places of work and at prices workers can afford; (2) promoting greater uses of public or mass transportation; and (3) locating new employment areas away from existing concentrations that are producing congestion."[1]

The same report also notes the dilemma of congestion resulting from increased accessibility: "The reciprocal relationship of land use and transportation can be illustrated by the corridor between El Camino Real and Bayshore Freeway. The existence of the original Bayshore Highway and El Camino Real was an inducement to development within the corridor, particularly of inductrial land uses that could make use of the rail line running down the middle of the corridor. Convenient access facilitated commuting by the employees of firms located within the corridor. This growing concentration of plants and employees congested the then existing system. The reconstruction of Bayshore Highway to a freeway was, in part, a product of the increased congestion. Now, it appears that even this freeway may soon be overloaded as more firms and employees are attracted to the area. The cycle of improved facility, increased usage, and finally congestion may well be repeated within a short span of time."

---

1. Land Use Issues in Santa Clara County, County of Santa Clara Planning Department, December, 1963.

Exhibit 1 - Traffic versus Time of Day in Chicago



From: <u>Chicago Area Transportation Study</u>, J. Douglas Carroll.

EXHIBIT 2

REQUIREMENTS FOR A MODERN RAPID TRANSIT SYSTEM FOR THE SAN FRANCISCO BAY AREA

One of the fundamental principles governing the development of a rapid transit system for San Francisco is that such a system must embody the most modern transportation concepts. It must be adequate for the traffic demands of not only today but also many years in the future. It must demonstrate an efficiency that will justify the pride of the community and the admiration of urban transportation planners everywhere.

If the San Francisco Bay Area system is to perform so satisfactorily and establish such a reputation, it must meet some very high standards of performance. These standards are the product of several years of planning. They reflect very specific decisions on basic design, operating capacity, and aesthetic considerations:

1. The system must be dependable and safe.
2. The system must provide convenient passenger distribution and collection, including fast and easy transfer from private automobiles and feeder bus and rail lines.
3. Vehicles must be fast—capable of maintaining a high average operating speed of approximately 50 miles per hour, including station stops. (To accomplish this, the equipment must be capable of reaching an acceleration rate of three to four miles per hour per second and a top speed of 80 miles per hour.)
4. The vehicle must be comfortable, with smooth riding qualities, adequate ventilation, control of temperature, and freedom from fumes.
5. The entire system, both vehicles and structures, must be aesthetically pleasing.
6. Vehicles must be quiet enough to permit normal conversation between passengers.
7. The system must possess a high degree of flexibility, to permit changes and additions in routing, scheduling, and vehicle combinations, and to take advantage of technological advances as yet unseen.
8. The system must possess a high level of capacity, an ability to carry up to 30,000 seated passengers per hour in each direction during peak hours.
9. The system must be adaptable — capable of operating on the ground, *under* the ground, and *above* the ground. (For example, substantial portions of the routes in high density commercial areas will have to be constructed underground in order to preserve existing aesthetic qualities and commercial activities.)
10. The system must lend itself to electronically controlled operation and fare collection.
11. The system must be as economical to construct and operate as possible, consistent with the above standards.

All of these requirements are necessary to assure acceptability of the system in a community with unique aesthetic standards, to make it as appealing as other forms of transportation, and to permit economical construction and operation.

It was against these strict standards that the consulting engineers evaluated each of the rapid transit schemes. The following section describes some of the most promising of the systems investigated by Parsons Brinckerhoff • Tudor • Bechtel and the basis for elimination of all but one.

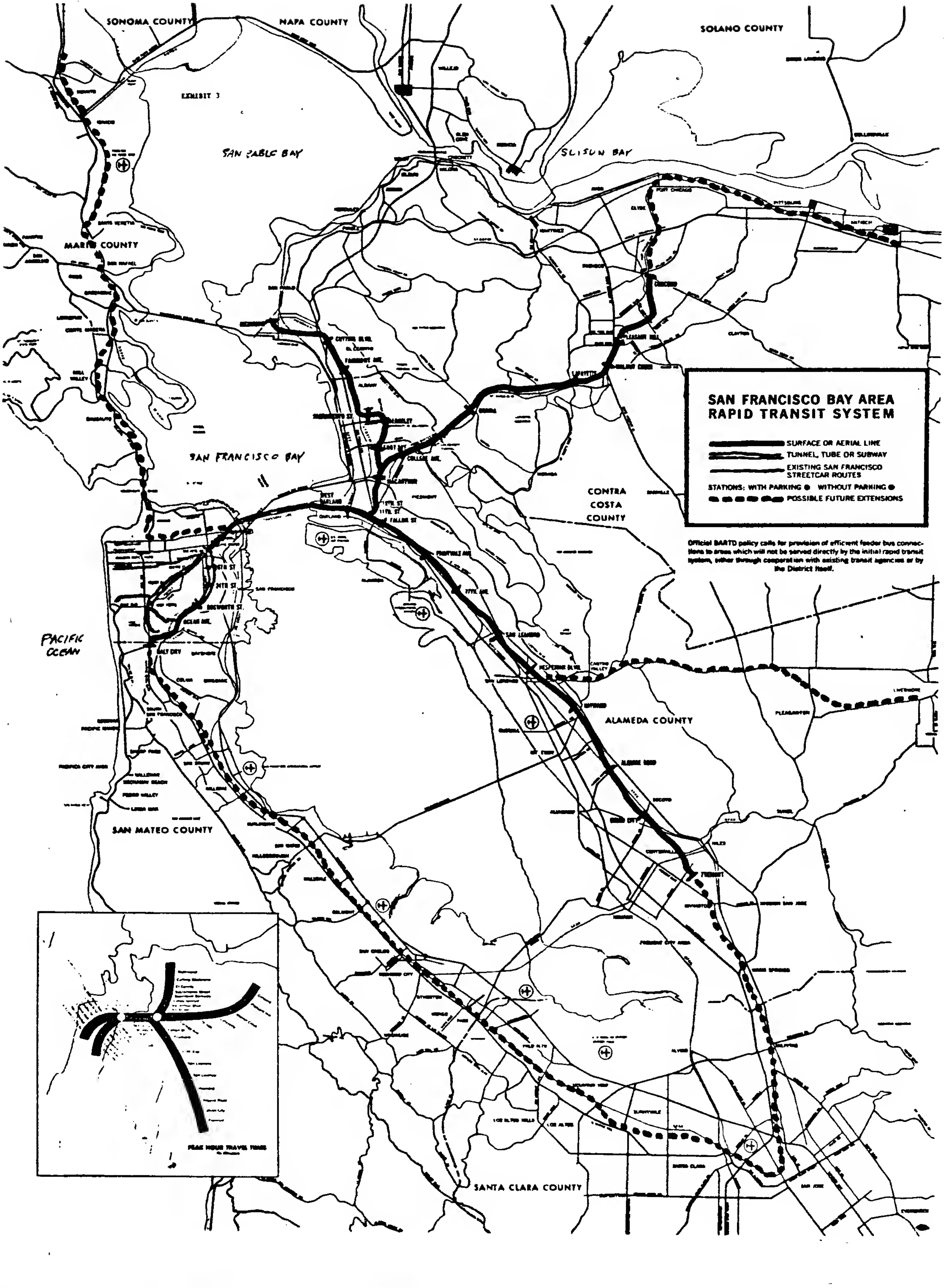


EXHIBIT 3
SONOMA COUNTY
NAPA COUNTY
SOLANO COUNTY
SAN PABLO BAY
SUISUN BAY
MARIN COUNTY
SAN FRANCISCO BAY
CONTRA COSTA COUNTY
PACIFIC OCEAN
ALAMEDA COUNTY
SAN MATEO COUNTY
SANTA CLARA COUNTY
SAN FRANCISCO BAY AREA RAPID TRANSIT SYSTEM
SURFACE OR AERIAL LINE
TUNNEL, TUBE OR SUBWAY
EXISTING SAN FRANCISCO STREETCAR ROUTES
STATIONS: WITH PARKING ● WITHOUT PARKING ●
POSSIBLE FUTURE EXTENSIONS
Official BARTD policy calls for provision of efficient feeder bus connections to areas which will not be served directly by the initial rapid transit system, either through cooperation with existing transit agencies or by the District itself.
WEST OAKLAND
LAFAYETTE
PLEASANT HILL
CONCORD
SAN LEANDRO
FREMONT
DALY CITY
OCEAN AVE.
24TH ST.
16TH ST.
PEAK HOUR TRAVEL TIME

URBAN TRANSIT (B)

Hybrid Automobile Helicopters

Rotary-wing vehicles capable of being driven on the ground as well as flyable have been suggested repeatedly by professional engineers as well as popular journalists. Flying prototypes have been attempted with varying degrees of success, but as yet no companies have seen sufficient commercial promise to justify development for production. A number of obstacles, including technical, economic, and legal problems are said to be in the way of practical utilization of hybrid helicopters. Advocates, however, point to the increasing congestion of ground transportation and to the advances of technology which they contend make the development and use of such vehicles continually more feasible.

Some pictures and data on existing helicopters appear in Appendix 1.

Feasibility Obstacles Suggested

1. Structures - If the vehicle is to be flyable like a conventional helicopter and also roadable like a conventional automobile, the structure must be suited to both modes of operation. Shocks of driving on the ground are often much more sharp and severe than those of flying. One helicopter company, for instance, found that its machines were damaged when shipped by train. The repetitive bumping of the rails caused brinelling of the main rotor bearings.

Allowance in ground operations would also have to be made for the possibility of collisions. Such collisions might cause damage to the airframe which would not be noticed until it was too late, in flight.

Automobiles and helicopters have quite different load paths. In a helicopter, the main load is supported by the rotor, whereas in an auto the main load is supported up through the wheels. How to provide the required structural strength for both modes of operation without making the machine too heavy to fly is a question not yet answered. For instance, the structure, less engine, of a two man helicopter is around 600 pounds. The maximum ratio of useful load to empty weight on recent designs at present is about 1.1. In 1950 is was around o.4.

2. Economics - The purchase price of a helicopter at present is about $22,500 for a two place machine, $35,000 for three place and $70,000 for four. The two place machine uses a reciprocating engine of 180 horsepower

 Prepared in the Design Division, Department of Mechanical Engineering, Stanford University by John M. Leslie and Karl H. Vesper as a basis for engineering class projects

weighing around 350 pounds and selling for about $700. Gas turbines are much lighter, weighing as little as 0.5 pounds per horsepower, but they are also much more expensive at present, a minimum price being around $16,000 for one of 250 horsepower. At very high purchase volume, it has been estimated by the manufacturer that this price might drop to a minimum of $5,000. It has been suggested that the use of a gas turbine in a few present Chrysler automobiles raises hope that still lower prices for such engines might be realized.

Operating costs of a two place helicopter at present are around $15. per flight hour at a cruising speed of about 80 mph. A major part of this is maintenance expense, which may run from 1/2 to 3 manhours per flight hour. Frequent inspection is required on many of the parts, such as the power transmission system and engine. Overhaul periods are short on some parts and longer on others. Time allowed between overhauls has grown, the life of rotor blades, for instance, having become indefinitely long, but inspection is still periodically required. If unusual incidents, such as temporary overspeed, earlier inspection is done. Many of the inspection procedures are quite elaborate and must be done by specialists.

Fuel economy is confined by a maximum lift/drag ratio of around 5 in present helicopters. Fuel consumption depends greatly on operating speed and altitude. A four place helicopter powered by a reciprocating engine can fly about 6 miles on one gallon of aviation gasoline costing about $.40 per gallon. The same aircraft with a turbine engine will have a comparable rate of consumption, but the fuel costs about $.20 per gallon. Helicopter engineers have expressed doubt that the lift/drag ratio for rotary wing machines can ever be raised above 6.

3. Traffic Control - "How many helicopters are going to be up there?," asked one engineer. "You need too many or you can't afford them".

Today helicopters depend on vision to avoid collision. Since helicopters can move up[1], down, backwards, forwards, and sideways, there are many ways collision can occur. It has been suggested that some reliable collision prevention device would be essential if there were to be many helicopters in the air. Such a device would be particularly important when vision was obscured.

Even with collision prevention devices, some argue there would have to be more formal traffic control, perhaps analogous to the prescribed air routes imposed on airlines today. What the rules should be and how they should be enforced has not been described.

4. Safety - Commenting on the training of helicopter pilots, an engineer said, "Flying a helicopter really isn't hard, but it does involve a different habit pattern from that of driving, just as flying an airplane does. Helicopter pilots

1. Maximum rate of climb for 2 place craft is around 1400 ft/sec. Maximum rate of vertical ascent is about 450 ft/sec.

today are more rigorously screened than auto drivers, though. The average auto driver won't even pay attention to his temperature gauge. In a helicopter it is essential that he pay attention to many instruments in addition to a sphere of surroundings.

In the event of engine failure, today's helicopters can be "glided" to a safe landing. As the machine descends, the main rotor "autorotates" and provides lift. Such emergency landing normally requires slightly more landing space to allow for approach and reduced controllability. The minimum rate of descent in glide is about one foot vertically for every four feet horizontally. Existing helicopters must have a run of at least 250 feet in takeoff to clear a 50 foot high obstacle and yet be able to autorotate to a safe landing in event of engine failure at any time during the ascent.

5. Legal - Many communities, including Washington D.C. and most suburban communities, prohibit helicopter landing within their boundaries. Repeated attempts by would-be purchasers of small helicopters to obtain permission to fly to and from their homes have met with failure. Some of the reasons cited are noise, the possibility of engine failure, and the danger of swinging rotor blades on the ground.

If the helicopter were to be driven as a car, the State vehicle laws would apply, requiring horns, headlights, windshield wipers, license plates, mufflers, and other accessories which, some engineers point out, would add greatly to the weight of the helicopter, possibly making it unflyable.[1]

At the same time, the vehicle would have to conform to Federal laws of certification for flight, including, for instance, requirement of dual ignition systems on reciprocating aircraft engines.

6. Space - For takeoff and landing, helicopter manufacturers recommend a flat clear space with a diameter at least three times that of the main rotor. Main rotor diameters are around 35 feet for two place craft. Collapsible rotors have been developed and successfully used.

Future of Hybrid Helicopters

"We tend to be pretty pessimistic on this subject," commented an engineer of one company manufacturing helicopters. "We've looked at the problem and just don't see a way to solve it for the present.

"It normally takes about 10 years from the initial planning stages to get a new helicopter into operation in the field. Right now we are making plans for machines to be available in 1977, and a hybrid helicopter isn't among them. The hybrid wouldn't drive as well as a car and it wouldn't fly as well as a helicopter.

"A better approach, it seems to us, would be to approach the use of helicopters from the point of view of what they are best qualified to do, rather than trying to adapt them to something to which they are not suited."

---

1. Vehicles traveling on state roads in California are required to be no wider than 8 feet.

Another engineer added, "perhaps our next logical step would be to work on intermediate systems. One could be to design a combination of helicopter and scooter. The helicopter would carry the scooter, and on the ground the scooter would be used to and from the helicopter. A problem here, of course, would be what to do about rain.

"Another possible interim step might be some kind of hopping device. It would travel along the ground, perhaps like a ground effect machine, but it would have features enabling it to up and down hills, and to hop over obstacles, perhaps using some sort of limited energy storage.

"For the far out future, maybe we could look for some sort of anti-gravity device for a solution. So far, we haven't really made any very radical departures. We use motors operating on long proven principles, and we fly by the long used method of deflecting air. People are working to find real departures such as anti-gravity methods. Perhaps we should be looking forward to them.

"Someday somebody is going to make a big improvement in personal transportation. The traffic congestion of our cities is making it essential, The question is, how and when.

Appendix I

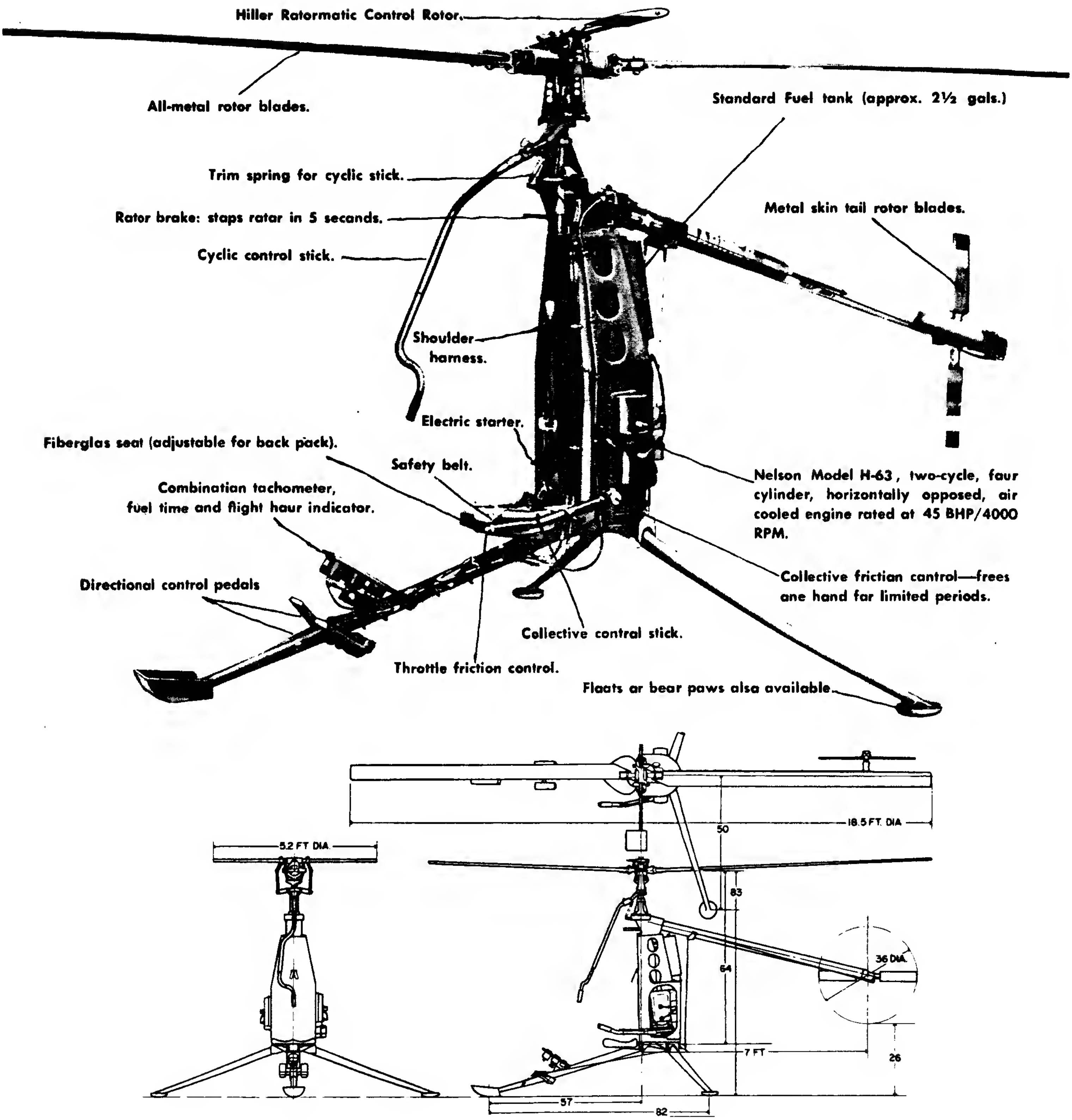

Hiller Rotormatic Control Rotor.
All-metal rotor blades.
Standard Fuel tank (approx. 2½ gals.)
Trim spring for cyclic stick.
Rotor brake: stops rotor in 5 seconds.
Metal skin tail rotor blades.
Cyclic control stick.
Shoulder harness.
Electric starter.
Fiberglas seat (adjustable for back pack).
Safety belt.
Combination tachometer, fuel time and flight hour indicator.
Nelson Model H-63, two-cycle, four cylinder, horizontally opposed, air cooled engine rated at 45 BHP/4000 RPM.
Directional control pedals
Collective friction control—frees one hand for limited periods.
Collective control stick.
Throttle friction control.
Floats or bear paws also available.
5.2 FT DIA
18.5 FT DIA
50
83
64
36 DIA
7 FT
26
57
82

EXHIBIT 1 (B)

REPRESENTATIVE

DIRECT OPERATING COSTS

FOUR PASSENGER HELICOPTER

1. Labor requirements through 1,000 hr. overhaul

Daily checks	:30 X 250	125 hrs.
50 hr. inspection	2:00 X 10	20 hrs.
100 hr. inspection	10:00 X 9	90 hrs.
Special items at 200, 300, 500 hrs.		40 hrs.
Engine change at 900 hrs.		40 hrs.
1,000 hr. overhaul		200 hrs.
Non-scheduled maintenance		100 hrs.
	Total labor	615 hrs.

Labor cost for 1,000 hrs. operation at \$5.00/hr. = 3,075.00

Labor cost	3.08/hr.

2.	Hourly allowance for spare parts, including major overhaul	2.97/hr.
3.	Reserve for replacement of finite life items	4.12/hr.
4.	Engine overhaul, including parts and labor $\frac{\$1400.00}{900 \text{ hrs.}}$ =	1.56/hr.
5.	Fuel and lubricants	

Fuel 17 GPH at .40/gal.	6.80	
Oil .5 qt./hr. at .55 qt.	.28	
Grease and miscellaneous	.09	
	7.17/hr.	7.17/hr.

Total E4 Direct Operating Cost	\$18.90/hr.

Performance

BOEING T60-BO-2 GAS TURBINE

1. Currently being developed by the Bureau of Aeronautics.
2. Under this program, ratings are:
   Military (30 minutes)—430 HP
   (Standard day, sea level)
   Normal (maximum continuous)—375 HP
   (Standard day, sea level)
3. This engine will supply all the power the transmission, as presently qualified, can use under standard conditions or at higher ambient temperatures and altitudes.
4. Although the specific weight of the T60 is somewhat higher than the T63, the T60 has the advantage of:
   Higher output power
   Operational ruggedness
   Availability six months before T63
   Background of testing under BuAer cognizance
   Reliability and low cost
   Favorable specific fuel consumption
5. The T60 engine is expected to grow to 500 or 525 HP Military rating.
6. Specific fuel consumption is expected to improve with the higher HP ratings.
7. A considerable weight reduction is expected. A 35 pound reduction can be obtained with relatively minor revisions, decreasing weight from 325 to 290. Further reductions are foreseeable which could reduce engine weight to 260 pounds.
8. In conjunction with Boeing and Bendix, Hiller dynamicists have already done extensive analog computer work concerning:
   Control stability for rotor, turbine systems.
   Flight properties of turbine-powered aircraft.

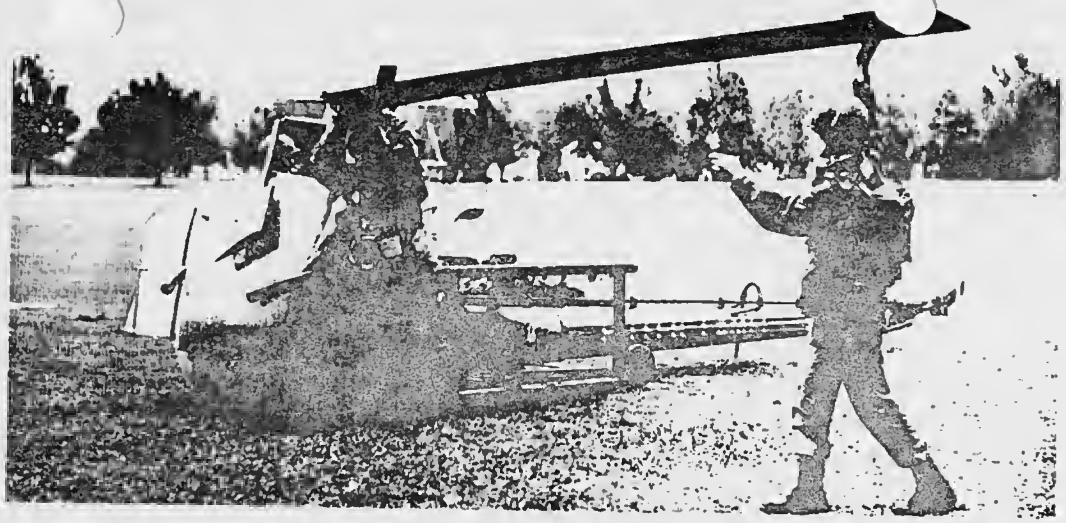
PERFORMANCE SUMMARY

ENGINE	ALLISON T-63			BOEING T-60	
MISSION	Normal Utility	Overload Utility	High Performance Reconaissance	High Performance Reconaissance	Normal Utility
Weight Empty (lb.)	1350	1350	1500	1650	1500
Fuel	300	300	500	700	300
Pilot	200	200	200	200	200
Payload/Endurance at S.L. (hrs)	1000/2.0	1150/1.9	200(obs)/3.7	200(obs)/3.8	1000/1.5
Gross	2850	3000	2400	2750	3000
Max. Speed at S.L. (MPH)*	98	97	107	120	113
Hover Ceiling (ft) (O.G.E., Standard Day)	9000	7000	14,900	16,500**	14,200**
Hover Ceiling (ft) (I.G.E., Army Hot Day)	7100***	4900***	10,900	13,100	9900

* Based on Modification of Rotor System.
** Compressibility limited.
*** With Water Injection.
T-63 Engine Rating 266/312 HP Except Where Noted. Hover Performed at Mil Power.
T-60 Engine Rating 350/400 HP. Hover Performance at Mil Power.
Endurance Mission Assumes 10% Reserve, 2 Min. Warm Up and Mfgrs. SFC Data Inc. 5%.
Army Hot Day Is 57.4 F Over Std. Temp. Equiv. to 6000-95°F.

ALLISON T63 GAS TURBINE

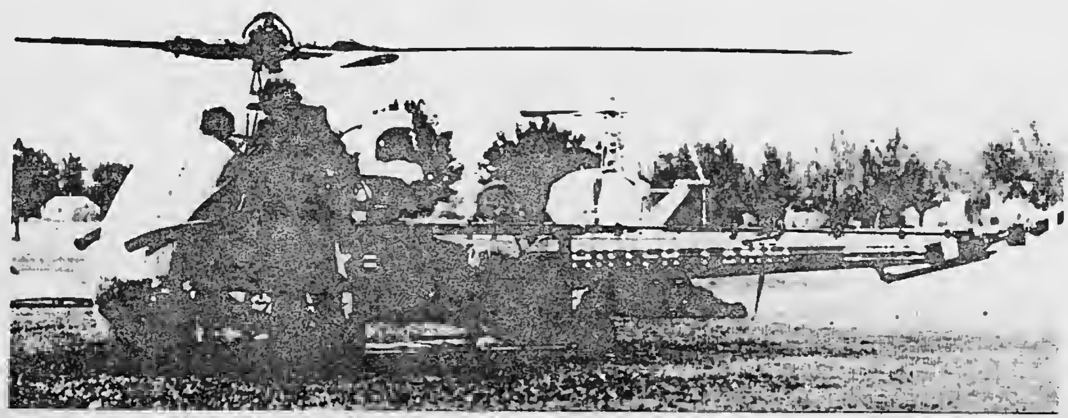
1. Currently being developed by the U. S. Army.
2. Under this program ratings are:
   Military (30 min.)
   250 HP (Std. day SL to approx. 9300 ft.)
   250 HP (100°F ambient temp. SL)
   Normal (max. continuous)
   212 HP (Std. day SL to approx. 10,400 ft.)
   207 HP (100°F ambient temp. SL)
3. Designed to the latest state of the art.
4. Since the engine carries military and normal power to altitude, as indicated above, the engine power section has considerable growth capability. With improved gear box load carrying ability, development should bring military power into the 300-HP range.
5. Hiller dynamicists have also done considerable analog computer work with the T63.



The unfolding procedure is begun by extending the main rotor blades and pinning the blade drag links.

Like Hiller's YROE-1 Rotorcycle, the unfolded CAMEL is secured by standard (NAS 1333 through 1346) quick-release, positive-lock, single-action pins.

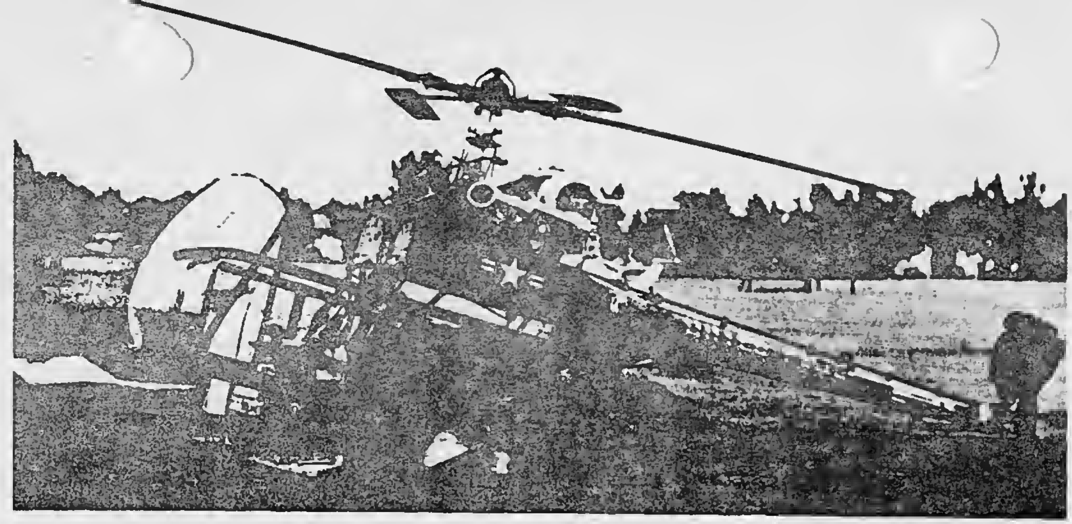
The Hiller Rotormatic control paddles are unfolded and pinned.



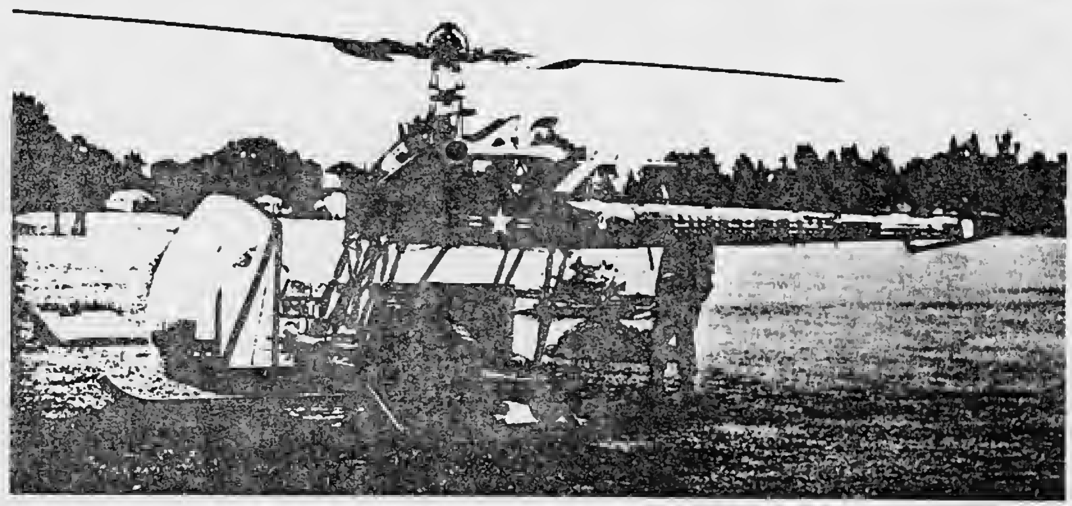
One man erects the main body of the CAMEL by turning the hand operated winch, which is permanently installed in the tail boom transition. Quick-release pins lock the main body in flight position.

EXHIBIT 3 (B)

By using the tail boom as a giant jack-handle, the CAMEL body is raised and the landing gear is dropped to flight position. The ground handling wheels and cargo platform act as alternate fulcrums in this operation.



The landing gear is locked in place and the cargo platform secured in the horizontal position. The cargo platform may also be folded and locked against the back of the cockpit to permit slingloading or installation of special equipment, such as wire-laying gear.



The cockpit roof is secured with standard cowl fasteners. Doors and other accessories may be added at this point.

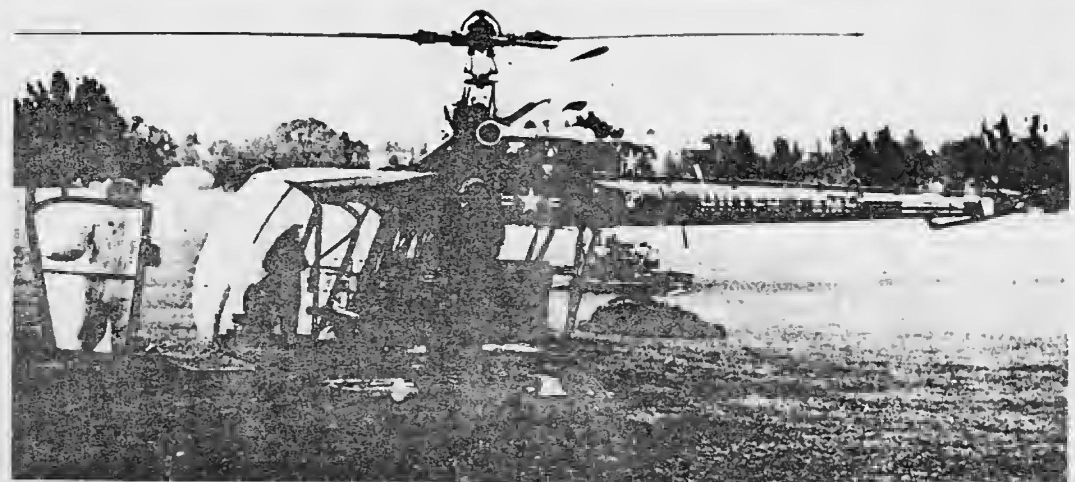
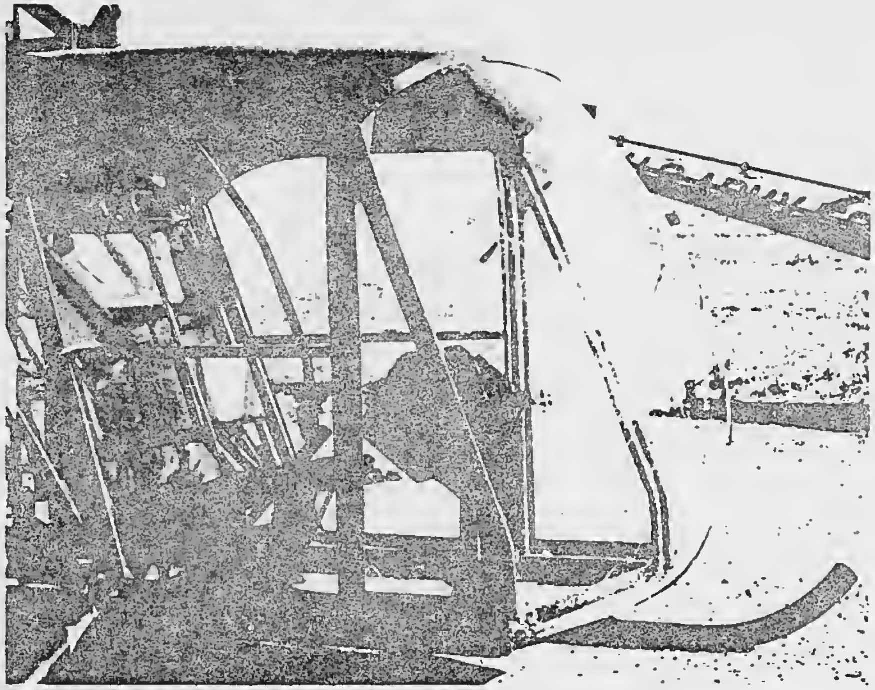
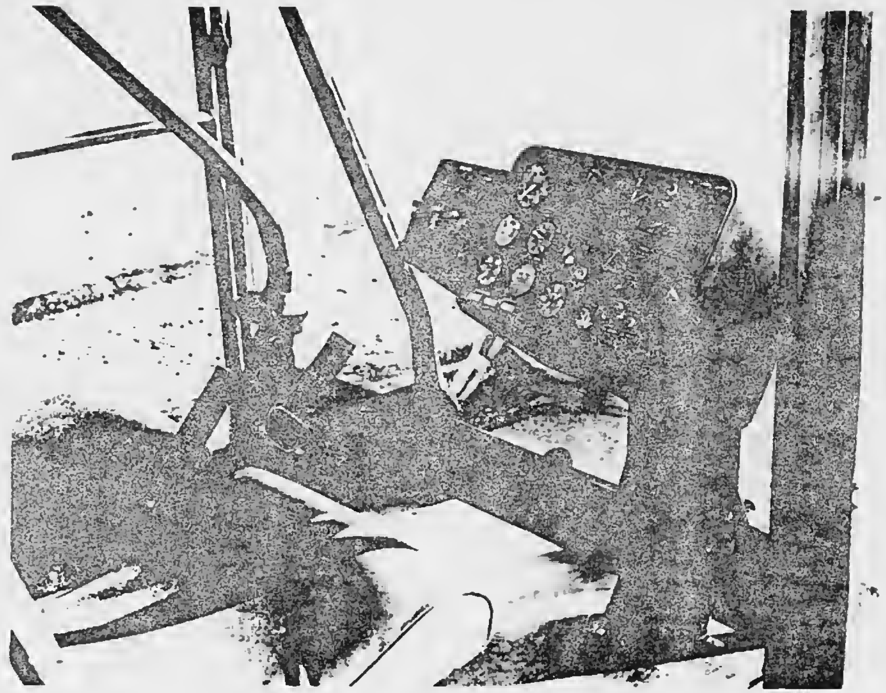


EXHIBIT 4 (B)

Design Features





TWO-PLACE CABIN

Two seats are permanently installed in the cockpit for the basic two-place configuration. As a two-place helicopter, the CAMEL will effectively meet the requirements of observation, surveillance, target acquisition, fire adjustment, courier, and liaison missions. For reconnaissance missions, special electronic equipment may be readily installed behind the seat back.

The cockpit was designed to standard HIAD dimensions. This provides greater room for pilot and observer and leaves ample space for radio and electronic gear and an improved foot pedal arrangement. Inertia-reel shoulder harnesses are provided.

The optimum in visibility is obtained by means of a low cockpit, compact instrument console and rear and overhead windows.

The photographs above show the mockup with an overhead cyclic stick installed. In addition to the cost and weight advantages and simplification of the folding arrangement, the overhead stick also makes the cockpit easy to leave or enter and is easily deflected in case of crash. However, since a great number of pilots are now trained to use a floor stick, this alternate type of control is available if preferred.

TRAINING

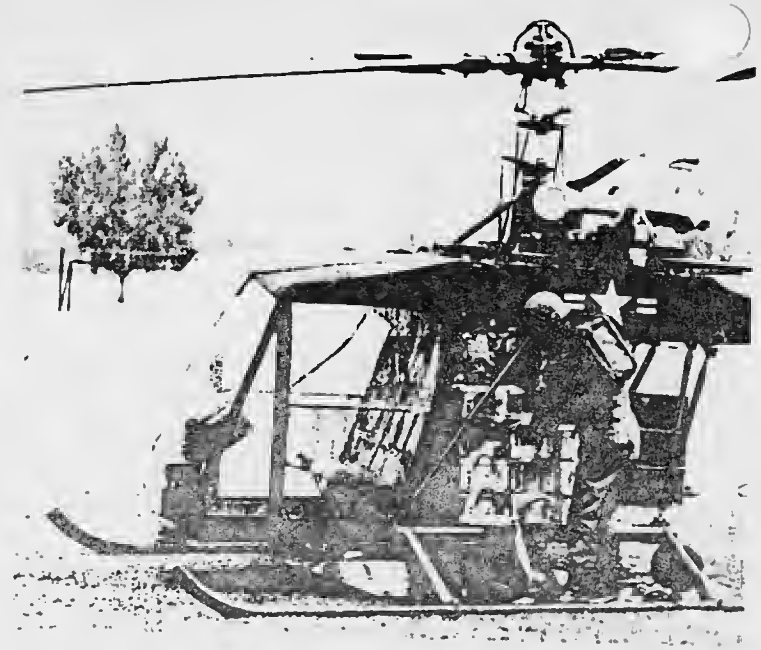
Although the basic CAMEL is equipped with single controls and an overhead cyclic stick for simplicity, light weight, and foldability, these controls may be replaced with dual sticks for flight training. With doors, canopy, and an auxiliary fuel tank added, the CAMEL remains a lightweight, high-performance, training helicopter. Endurance for the training mission is 4¾ hours.

CARGO VOLUME

Fundamental to the CAMEL design is the large cargo volume located directly below the rotor column. It is the utility of this volume which makes the CAMEL more versatile than any existing small aircraft.

Under combat conditions, simple seats can be installed which will equip the CAMEL to carry four Marines, each with complete combat equipment (240 lbs. each), or five lightly equipped Marines, plus pilot, as far as 130 miles.

The standard cargo platform can be used for baggage and weapons storage in connection with the seating provisions. Since the troops face outboard, immediate deployment after landing is possible. Weather protection can be provided for the troops when necessary.



CAMEL PICKUP

This shot shows the CAMEL in its role as a flying pickup truck. The cargo area, located directly below the center of lift, may be loaded from either side or from the rear. Cargo lashings may be easily secured by means of flush quick-disconnect fittings on the underside of the fuselage box and on the platform. Side nets may also be installed in a similar manner to carry loose, bulky loads.

The more than 60 cubic foot cargo space may be utilized to carry water, rations, ammunition or fuel. Four 55-gallon drums, like the one behind the CAMEL, may be accommodated easily on the cargo platform.

EXHIBIT 6 (B)

ENGINEERING CASE LIBRARY

ECL 11

URBAN TRANSIT (C)

Human Factors in a Hybrid Automobile-Helicopter

The concept of the hybrid automobile-helicopter is of particular interest to the Company for which each of you work as a "human factors engineer." In this particular Company, the chief engineer recently established a team of "experts" to study the practicability of having an advancement in the state of the art by the year 1980 that would allow the design of a low cost, highly reliable, hybrid automobile-helicopter. You, as the "human factors" experts soon will be called upon to make a major contribution to the overall effort.

The preliminary studies by the other members of the Company Team have been very encouraging. They have shown that it will probably be feasible, at least technically, by the year 1980 to build the desired vehicle. If they are correct, such a vehicle could travel in a manner similar to a present day Volkswagen. It could be driven to an open area designated for "take off" and then flown to the closest landing spot near the driver-pilot's destination; then it could be driven to the exact destination. The vertical take off and landing characterictics of the vehicle should enable the "take off" and "landing" areas to be nothing more than twenty-five foot radius clearings in parking lots, on top of large buildings, special cul-de-sacs, etc. The hover capability of the vehicle should enable the establishment of appropriate air traffic control in designated air corridors.

The tentative specifications for the planned vehicle for the year 1980 are as follows:

Initial cost (1964 dollars)	$5,000
Passengers, including driver-pilot	2
Additional baggage	100 lbs.
Ground speed maximum	60 mph
Air speed cruising	80 mph
Service ceiling	8,000 ft.
Hover capability	4,000 ft.
Rate of vertical climb (maximum)	400 ft/min.
Rate of climb (maximum)	1,000 ft/min.
Autorotation descend rate (maximum)	1,800 ft/min.
Fuel capacity: Flying	2 hrs.
Driving	150 miles
Weight	1575 lbs.
Size: Length	10 ft.
Width 4 1/2 ft. Height	5 ft.
Fly: Length (less rotor)	16 ft.
Width (less rotor)	4-1/2 ft.
Height 5-1/2 ft. Main rotor dia.	22 ft.

The preliminary studies have shown that the design of the new vehicle will depend heavily upon breakthroughs in the following areas:

1. Highly reliable, low cost, low weight, turbojet engines for the rotor tips.

2. Strong materials yet light in weight and low in cost (improvements over present day magnesium, titanium, fiber glass, etc.)

3. Design of both hinged main rotor and telescoped tail boom to assure a light weight, low cost, yet reliable vehicle.

4. Design of automatic controls to compensate for changes in temperature, humidity, weight distribution, etc. to allow the vehicle to approach the ease when being flown as it has when being driven.

5. Human factors considerations involving both safety and comfort of occupants and safety and disturbance of the general public.

The vehicle as it is now envisioned (this is tentative and is subject to change as a result of the pending studies by your group) will use two tip turbojet engines of eighty horsepower each, there will be one on each tip of a two-bladed main rotor. This scheme will not only provide the redundancy of a two-engine helicopter but will also eliminate the necessity for the tail rotor to overcome the anti-torque of the main rotor; the tail rotor will be used for steering only and will derive its small amount of power from the main rotor shaft. In case of failure of both turbojets, the vehicle will autorotate, hopefully, to a safe landing.

The main chassis of the vehicle will be made from tubular Magnatitanaglass® our Company's trade name for a new light-weight material we feel we can develop. The cabin will be made from an advanced type of Plexiglass that has increased strength for a given weight. The exact size and shape of the cabin and the final clear window areas will depend primarily upon your decisions.

The vehicle for land travel will have three wheels, two in the front and one in the rear. The rear wheel will be driven by a 50 horsepower combination turbine engine and torque converter coupled through a simple reverse/forward gear box; this engine will be located rear of the seat (similar to a Volkswagen). Steering will be accomplished by the front wheels. A liquid suspension system will be used. The vehicle will be equipped with two head lights, two combination tail/stop lights for land travel, and appropriate lights for night air travel. There have been no decisions made as to the type of controls and instruments that might be in the cabin. Such decisions await the completion of your studies.

The aeronautical engineers assure us that the helicopter flight characteristics will be extremely well behaved; they say that the stick can

® Registered 1964

increase altitude, pushed forward to descend, and pushed to left or right to turn left or right. Hovering could be accomplished by depressing a button. The engineers who will be responsible for designing the main frame believe that the conversion from land configuration to flying configuration can be accomplished by simply rotating a lever in the cabin from one position to another. In the "flight" position the main rotor would open out, the tail boom would extend, and the tip turbojets could be started; the whole operation would take only 15 seconds. In the "drive"position, the tip turbojets would be interlocked so that they could not be run.

Preliminary studies of weight and weight distribution show the 1,575 pound gross weight to break down as follows:

2 persons (180 lbs. each)	360 lbs.
Baggage	80
Gasoline (26 gals. at 6 lbs/gal.)	156
Tip turbojets (40 lbs. each)	80
Turbine/torque converter	50
Main rotor systems (less turbojets)	150
Tail rotor system	50
Chassis, suspension systems and wheels, steering apparatus, brakes, bumpers	375
Battery, starting motors, lights and automatic controls, and control mechanisms	150
Cabin (external shell)	50
Seats (15 lbs. each) and furnishings	40
Instrumentation and communications equipment	34
	1,575 lbs.

<u>Assignment for Human Factors Engineering Group</u>

The preliminary design has now progressed to the point where it is imperative to consider the multitude of interface problems between the technical hardware and the people who are going to fly or, in some way, be affected by the machine. Target dimensions and target weights have been established; these figures are not frozen and are subject to change if you have good reason to recommend same. Naturally, all members of the team realize the importance of having the lightest possible overall weight, the lowest possible frontal surface area, and the lowest possible drag coefficient commensurate with occupant comfort and safety.

Specifically, you are being depended upon to determine the following:

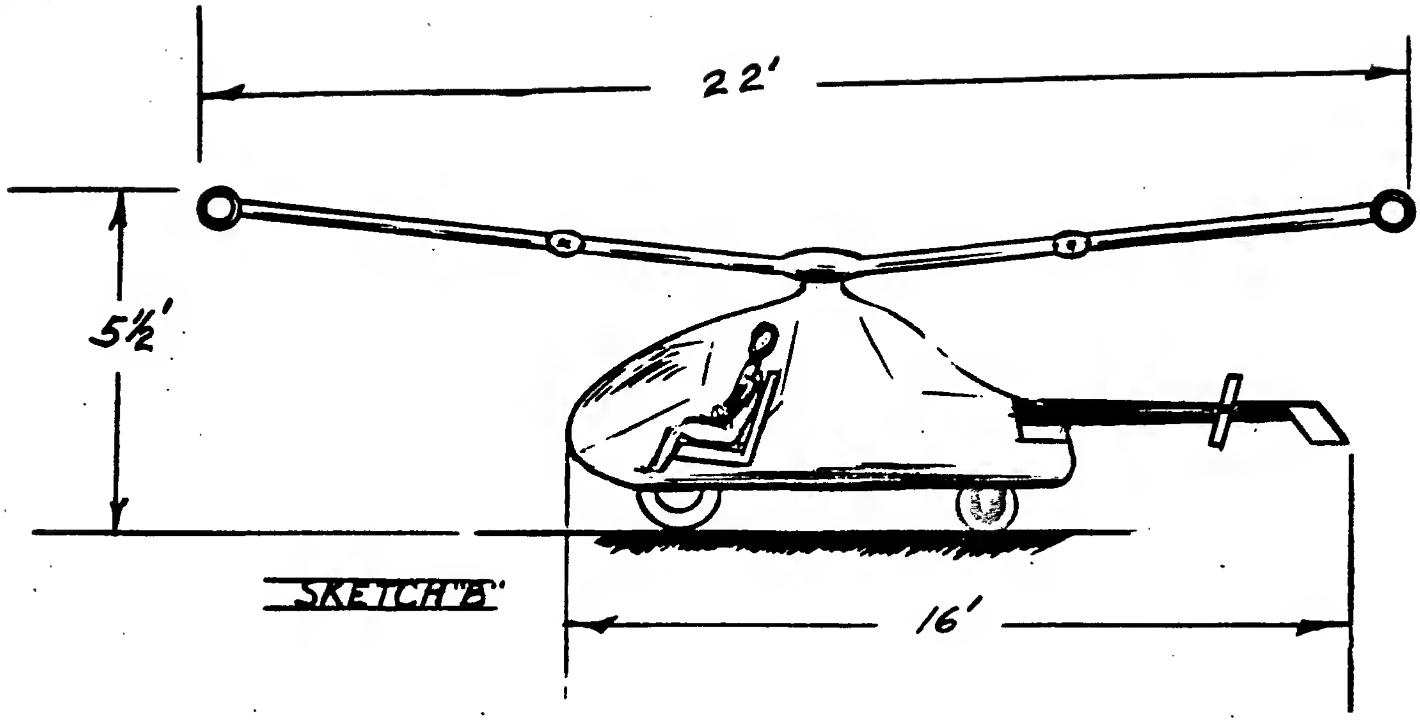
1. Cabin size - width, height, distance from back of seat to front of cabin. (Ignore the dimensions of the cabin to the rear from the back of the seat.)

2. Controls - functions, types, and locations.

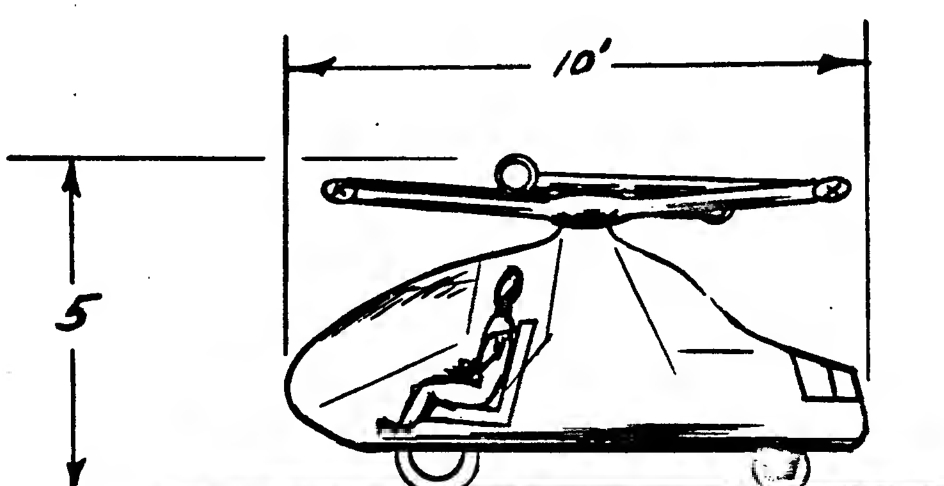
3. **Instruments** - to satisfy the design intent of this vehicle. (Your conclusions regarding "safety" will help determine the "intent".)

4. **Safety Analysis** - study safety aspects of hybrid vehicle as both automobile and helicopter under both good and poor weather conditions.

5. **Desirability Analysis** - consider, from the human factors aspect, the advisability of your Company designing this vehicle for use by the general population of the Peninsula.



SKETCH "B"



SKETCH "A"

EXHIBIT 1